with their pointed base terminating in "two foramina, which diverge and pass into the adjoining cell or cells."

Fig. 8. Side view of casts of marginal cells. This figure exhibits two young cells originating on the outer side of an old one, causing its aperture to be turned up, thereby giving its outward outline a geniculated form. The small cell to the right reposes completely on one of its sides.

Fig. 9. Side view of two cells, modified owing to the propinquity of the appendage, of which a cross section is represented.

Fig. 10. Gutta-percha impression, twice the natural size, of the upper surface, showing the somewhat circular and subpolygonal form of the cell-apertures. The marks * * indicate the probable situation of the terminations of the verniform appendage.

XIII.—*On the Mechanism of Aquatic Respiration and on the Structure of the Organs of Breathing in Invertebrate Animals.* By Thomas Williams, M.D. Lond., F.L.S., Physician to the Swansea Infirmary.

[With a Plate.]

[Continued from p. 42.]

Pulmonifera.

The leaf-like appendages of *Phyllodoce lamelligera,* which expose to the action of the aërating medium a true chylaqueous fluid, differ very little in intimate structure from the branchial laminæ of the Crab, the purpose of which is to distribute for respiration a current of blood, properly so called. But the tracheæ of Insects have no parallel amongst the respiratory systems of the Invertebrata. Compared with the respiratory organs of the water-breathing Articulata, these tracheæ constitute, in a complete sense, an apparatus invented *de novo.* Insects, with reference to the relations of this system, cannot therefore be said to be to the water-breathing Annulose and Articulated animals what the Pulmoniferous Gasteropods are to the water-breathing Mollusca. In the latter cases nevertheless, the aquatic and atmospheric systems are strikingly diverse.

In the instance of the air-respiring Crustaceans no change of structure whatever occurs in the respiratory system. The branchiæ of the terrestrial Isopoda are precisely the same in every detail of minute structure as those of the aquatic genera. The inference arises at once : these Crustaceans are merely modified water-breathers ! But when an animal is to be formed whose medium of life shall *permanently* be the atmosphere, a design in the construction of the breathing system is adopted involving express provisions, which stand at marked variance from every variety of the water-breathing machinery. It is accordingly observed that the contrast between 'the lung' of Pulmoniferous, and the branchia of the Branchiferous Gasteropods is almost as striking and irreconcileable as that which separates the trachea of the Insect from the breathing plume of the Annelid or the gill of the Crab. In the midst of the aquatic Articulata, the air-breathing Insect arises on the scene; in the midst of the aquatic Mollusca, the pulmonated Gasteropods are formed. The object being one and the same, namely to produce an air-breathing animal, the artificer being still within the limits of the Invertebrate subkingdom, the question is most natural, Are the means in the two cases also the same by which the one and the same end is sought to be attained? —No! they are most wonderfully and extraordinarily dissimilar. The tracheæ of the Insect pervade the entire substance of the body of the animal. The 'lung' of the Snail is a mere bag, inflated as if by some rude and fallible artist, under the skin of the back. The former charms the eye as it discovers the mingling of the infinitely perfect with the infinitely minute. The latter shocks the mind with disappointment as it views the characters of a contrivance at once coarse, clumsy, and inadequate. But is it so in reality, or is it so only because imperfectly understood, and because it is measured by a wrong and unfair standard? Is not such an apparatus, simple as it is, quite enough to sustain the sluggish vitality of these slow-moving and sleepy animals? And is not the *end in view* accomplished quite as perfectly as it is in the case of Insects, though by a machinery of incomparably greater apparent intricacy? These questions will well prepare the mind for the investigation of the actual details.

All the terrestrial and the majority of the freshwater Gasteropod Mollusks breathe air. They are provided with a pulmonary cavity or sac, whose walls are networked with vessels by which the blood is exposed to the aërating element. No form of branchiæ exists. The animals which present this organization are all provided with distinct heads and furnished with tentacula and organs of sight. They walk by the aid of a well-developed creeping disc. One large division of the land snails is supplied with an operculated shell; the rest are inoperculate and sometimes shell-less. The Pulmonifera are closely related to the plant-eating sea snails (Holostomata) through the Cyclomata, and to the Nudibranchs by *Onchidium*. As a group, the land snails are inferior to the sea snails, on account of the comparative imperfection of their senses, and the union of the functions of both sexes in each individual.

The typical inoperculate Pulmonifera vary in appearance and habits, but agree essentially in structure. The respiratory orifice is small and valve-like, to prevent too rapid desiccation in the land species, and to guard against the injurious entry of water in the aquatic tribes*. Hence they have been called *Adelo-pneumona* (or concealed-lunged) by Dr. Gray; the Operculata, by antithesis, being named the *Phanero-pneumona* or open-lunged.

The Onchidiadæ are sea slugs, breathing by means of a pulmonary cavity, but living immediately in contact with marine conditions. According to the dissections of Mr. Hancock, the "lung is placed in this group at the posterior extremity of the body, and has consequently the heart in front of it."

Respiration in the Limacidæ is accomplished by means of a cavity seated on the back near the neck, and covered by the disc (Pl. XI. fig. 1). It opens on the right by a valvular sphincteric orifice, which is endowed with an active power of widely dilating and of closely contracting (*e*). In this family the rectum does not traverse the respiratory chamber; it lies external to, and below its right boundary. The anal orifice therefore is separate from that of the respiratory; it is seen immediately below the latter. This is a fact of structural disparity between the Limacidæ and the Helicidæ. In the latter the intestine is a prominent object in the breathing-chamber, and the vent is confounded with the pulmonary orifice. The position of the generative outlet is variable.

The following description is founded upon numerous dissections of the common Slugs. The breathing-sac presents in all the species the same anatomical characters. It is best studied by fixing the animal with two strong pins, transfixing the body in front near the head and behind near the tail in a cork-bottom dissecting dish. One blade of a strong, blunt-pointed sharp scissors should be inserted into the pulmonary orifice. The point should now be carried round the boundaries of the chamber, the disc being cut as the instrument travels round. Such a section (fig. 1) will enable the lid of the cavity or the respiratory disc (*b*) to be so perfectly raised as to leave the entire space underneath quite uninjured. A part corresponding with the pericardium (*c*) will however be found to be adherent to this roof; it should be snipped with the scissors. The roof, in the substance of which is lodged the rudimentary shell, should now be reflected and pinned down (as shown in figs. 1 & 2). From the central space of the cavity a second membrane (fig. 1 *c*) will require to be raised. This is much more vascular than the former integumentary covering (*b*), and constitutes really a part of the respiratory surface. This structure serves also as peri-

* See the excellent Manual on Recent and Fossil Shells, by S. P. Woodward.

cardium. It overcovers the heart, and embraces the large curved gland, in the centre of the area bounded by which the heart (Pl. XI. fig. 1 *d*) is situated. A perfect view of this pulsatile body is thus obtained. It beats slowly, about 30 or 35 times in a minute; less frequently probably in an unmutilated animal. It consists of an auricle which is situated under or below the ventricle. The ventricle is not a linear continuation of the auricle, separated only by a constriction as it is in the Helicidæ, but a separate organ receiving the auricle by a laterally placed auriculo-ventricular orifice. It will be seen that the large blood-channels (fig. 1 *g*) which are distributed over the floor of the cavity, and which in nature are of an opake white colour, converge upon the auricle, and that the aorta (*h*) rising boldly up from the ventricle as a vigorous vessel of considerable calibre, pierces the base of the chamber and disappears, travelling backwards among the viscera.

Now of the Limacidæ it cannot with truth be said that they are either Proso-branchiate or Opistho-branchiate. The heart here is certainly not placed either before or behind the respiratory organ, but in its true centre. The ovoid space circumscribed by the gland (c', c'), and roofed down by the pericardium, has only one opening through which the air can effect its ingress and egress. This opening corresponds to the point at which the line of the gland is interrupted. In some species it is placed at a point on the left side remote from the external orifice (*e*), in others behind; in others again it has an anterior position. That portion of the cavity which is without the gland, and between it and the outer boundary of the disc (*f*, *f*), forms a circle, so that the air may course around the cavity from right to left or reversely, according to the tendency of the muscular action by which it is impelled. The movements of breathing are far less manifest in the slug than in the snail. In the slug the pulmonary orifice slowly opens, and the bag is emptied by the slow expulsion of the air. The act of inhalation is performed in a similarly slow manner. The orifice now firmly closes, and remains closed until the next act of expiration, which may occur irregularly in ten minutes or a quarter of an hour.

Two points in the history of the respiratory cavity of the Limacidæ demand special attention. First, the structure and distribution of the vessels, and secondly, the character of the membrane or covering by which the cavity is lined. As a rule, it may be stated that the pulmonary vessels are distributed in the Limacidæ over the floor of the chamber, in the Helicidæ over the roof. In the former the mucous gland is considerably larger than in the latter. The heart of *Limax* lies, like the pulmonary network, on the bottom of the cavity; that of *Helix*, like its pulmonary *rete*, is located in the roof. These are features of striking dissimilarity.

The pulmonary vessels (*a*) of *Limax* are not, as in *Helix*, gathered into one large trunk, debouching in the auricle. They consist of several trunks, the cylinders of which are so superficially situated as to stand in prominent relief above the main plane of the cavity. This peculiar appearance results from the rigid calcareous walls of the vessels. It seems, according to the author's dissections, as if two or three veins in *Limax* opened into the auricle, but it is not easy to determine their exact number. The peculiar tenacious mucus secreted by the gland (c', c') which surrounds the heart (*d*) is poured out into the respiratory cavity. But although this is the case, it does not interfere with the function of the surface over which it is diffused. It does not become *adherent* to the latter. This mucus is capable of enclosing globules of air, and of becoming frothy. In this state it is frequently extruded from the pulmonary orifice. The study of these glands and their structure is for the present postponed, since they share in no way in the process of respiration.

Cuvier and the older anatomists supposed, when they observed the *white colour* of the vessels in the Limacidæ, that the phænomenon was due to the *milky* character of the blood by which they were filled. This is an error. The white colour results from the mixture of fat and chalk which abounds in the substance of the walls of the vessels, imparting to them a peculiar character and extraordinary thickness; such thickness as renders it extremely difficult to understand how they are not thereby disqualified for the office which they are designed to discharge. The larger vessels (fig. 1 *g*) stand upon a more superficial plane than the smaller ones. This disposition gives a *cellulated* appearance to the surface (fig. 2), like that of the inside of the frog's lung. It is an arrangement which, more completely than a smooth surface, detains the air in contact with the blood. But though a *tendency* to the cellular form is displayed by the pulmonary membrane, it must be understood that it is not *organized* after that fashion, as is the case with the lung of the frog.

The pulmonary vessels in the Pulmonated Gasteropods form but one sheet, that is, the blood traverses the area of aërating surface only *once*. The blood-currents converge upon the respiratory chamber from all parts of the body. Large trunks (fig. 2) may be seen at the sides of the cavity before, behind, and at the sides. These trunks are individually walled vessels; they are true pulmonary arteries. They subdivide into smaller vessels, and these break again into a network constituting the real lung of the animal. Near the position of the heart, they begin to reunite, large trunks becoming visible, which end in the auricle. The larger trunks are visible to the naked eye; the smallest require all the skill of the microscopist for their examination. The coats of the more visible white trunks are rendered colourless under the joint agency of dilute muriatic acid and æther: neither reagent alone will remove the white colour. The acid will dissolve the lime and leave the fat: the æther will remove the fat and leave the lime. The fat and the lime are contained in *cells*, and intimately mixed. The lime exists in the form of amorphous granules; it does not *crystallize* even in the rudimentary shell contained in the roof, but from the conical masses which adhere into groups in some places, it is evident that a tendency to crystallize is manifested.

It seemed to the author a point of extreme interest to determine whether the lime and fat which render the outline of these vessels, especially in the common Black Slug, so conspicuous, were incorporated in the substance of the vascular walls, and in what manner, or whether they were lodged in a tissue occupying the intervals between the vessels. These questions immediately arose. It appeared so utterly without precedent that vessels, destined to aërate the blood, the smallest, the most subdivided, the most thin-walled, the most naked of all the vessels of the body, in every other animal, vertebrate and invertebrate, should in the instance of the Limacidæ be encumbered with such thick, even inorganic, rigid parietes!

The physiologist is embarrassed in attributing to a machinery, by comparison so coarse and clumsy, a function so subtle and refined as that of breathing. But is it not presumptuous to pronounce a verdict of imperfection upon any of the works of Nature? Is it not possible that faultless skill and matchless adaptation of instrument to purpose, may yet reveal itself beneath the apparent characters of an organ which at present may appear rude and ill-contrived? It is more probable that Nature should be perfect than that her critic should be so.

A transverse section of one of the larger vessels will render it at once evident that each trunk is lined *internally* by a smooth non-calcified membrane, and that the lime-particles are deposited *only in the substance of the external coats.* The presence of this inorganic substance destroys the power of the vessels to contract upon their contents. The blood is circulated therefore through the pulmonary membrane by some other force than that usually due to the elasticity of the vessels. Although the fact is of difficult proof by direct demonstration, it is almost certain that the *exterior* of each vessel is also lined by a non-calcified membrane. It must be so, because active vibratile cilia unquestionably exist in various parts of the pulmonary cavity in every species of *Limax**.

If the internal and external coats of the vessels assume thus the characters of two concentric non-calcified cylinders, it follows that the mineralized layer must occupy the intervening space, representing the middle coat. This is probably the truth. But whether the external membrane and the lining of the cavity be separate structures or not, it is indisputable that the vessels are enveloped in a thick calcareous sheath. It is obvious, therefore, that the respiratory gases respectively leaving and entering the blood must traverse this dense septum,—a peculiarity quite without a parallel in the whole history of the organs of respiration. In the higher animals the pulmonary vessels in all classes are brought so near the aërating surface, that anatomists of eminence are not wanting who assert that such vessels are not covered by any kind of epithelium whatever. If then all structures interposed between the blood and the air are thus studiously reduced to the utmost extreme of tenuity in the higher animals, how is it that in these highly organized Gasteropods the respiratory vessels should not only be encumbered by thick coats, but by those of an inorganic nature?

Either in these animals respiration is reduced to a minimum, or these calcareous coats not only do not interfere with, but literally facilitate the interdiffusion of the gases. Although this idea presupposes a mechanism quite unique in the history of the breathing organs of animals, it involves nothing which contradicts the laws of endosmosis. The mineral which is deposited in the coats of the vessels is the carbonate of lime. It is impossible that such a substance could exert any chemical affinity either for oxygen or carbonic acid. The lime-particles are so loosely strewn together that they are separated by spacious interstices. Such a septum would present no obstacle to the diffusion of gases. In fact the endosmotic conditions of the beautiful experiment devised by Prof. Graham, in which he coated a coarse sheet of brown paper with a thin film of collodion, are precisely imitated in the vessels of the Slug. Prof. Graham found that the organic film so placed did not in the least degree diminish the rate of diffusion at which gases pass through a sheet of brown paper.

It is quite certain then that the vessels of the lung-sacs of the Limacidæ are *encircled* by the calcareous coats. The lime is not

* I invite especial attention to this point, because hitherto all anatomists have denied the existence of ciliated epithelium in the interior of the pulmonary chamber of air-breathing Gasteropoda. I have proved the fact of its presence beyond doubt, and by repeated observations.

deposited in *lines*, as the cilia are disposed along the branchial leaves of the Lamellibranchiate Mollusks, leaving a non-ciliated interval to which the active process of respiration is chiefly limited. The gases *must* consequently traverse the entire substance of the calcareous and membranous coats. The interstices between the calcareous particles might on this view be considered as each representing *a cell*, in which a small volume of air is held stationarily in intimate contact with the blood, and beyond the disturbing control of the ever-moving and varying parietes of the general cavity; and in which, as in the air-cells of Mammals, the interchange of the gases is a *continuous*, not an interrupted, process. But these permeable calcareous coats, while they divide the oxygen into myriads of infinitesimal portions, bringing it thus in a state of extreme subdivision into contact with the blood, act also like other porous bodies upon gases, by *condensing* their volumes. The power thus exerted increases the diffusiveness of the gases, and consequently augments the measure in a given time of the function of the part, because it virtually accelerates the interchange of the gases. The *ultimate* vessels of the abdominal organs are furnished with soft non-calcareous coats. The lime in these parts of the body is present only on the larger trunks. This substance is suppressed, therefore, in those organs in which its presence would interfere with the nutritive and secernent office of the minute vessels. Being present on those of the lung, the inference is unavoidable, that in this situation at least it does not obstruct the function of the organ. It seems on the clearest grounds that the mechanical subdivision of the air in a respiratory organ may be made to supersede the necessity for the subdivision of the blood by the formation of a *rete mirabile*. To this end in the Limacidæ a contrivance of singular simplicity is adopted: the air is made to rush in steady but infinitely divided currents in the direction of the blood. This is enough to secure the intended result. The blood accordingly flows in channels of comparatively large diameters. Coarse trunks separated by wide intervals, they contrast most strikingly with the elaborately formed parallel capillaries of the gills of all the branchiferous orders of Gasteropods, in which the blood-stream is reduced to the utmost minuteness.

On no other interpretation of the anatomical facts by which the pulmonary sac of the air-breathing Gasteropods is distinguished, is the reproach of rudeness and coarseness of construction to be removed. On this interpretation the rudeness is turned into subtlety and the coarseness into refinement, and the physiologist may cite indeed an organ which at first only shocked the short-seeing mind with a sense of disappointment, as only another illustration of the illimitable fertility of resource by which every part of every living mechanism is distinguished. It is only by such a contrivance that the *necessary surface* for the aërating process can be realized; for compare the area of this lung-sac with the extraordinarily multiplied superficies secured by the laminose arrangement of the gills in the branchiferous orders, and how considerably the latter will be found to exceed the former! In comparing a gill with a lung, even in the same class of animals, and organized on the same type, it is necessary to remember that in the former case the oxygen, dissolved in water, is brought up to the blood under certain opposing circumstances, and that a compensation is offered in the divided state of the blood, while in the latter a similar amount of work may be done with large vessels and coarse streams, in consequence of the unmixed and direct manner in which the active element is applied to the vital fluid.

The pulmonary chamber of the Helicidæ is distinguished by several anatomical particulars from that of the Limacidæ. In the Snail (fig. 3) the rectum (*a*) enters the precincts of the chamber, and the heart (*b*), mucus-gland (*g*), and pulmonary vessels (*d*) are seated on the *roof* (*h*) of the cavity. In the Slug, as already detailedly explained, the rectum is external to the chamber, and the heart, gland, and pulmonary *rete* are placed at the bottom of the cavity.

Helix aspersa (figs. 3, 4 & 5) is the best, because the most familiar, example of the family of the Helicidæ. In it, as compared with *Limax*, a marked deviation is observed in the position of the mucus-gland. That of *Helix* presents the appearance of a soft oval mass (fig. 3 *g*) situated to the right of the heart when *in situ*; it is considerably less developed than it is in *Limax*. This proximity of place to the heart has probably some meaning which is not yet understood. But in structure the gland is the same in the two families. The auricle (*c*) and ventricle (*b*) of the heart in *Helix* are placed on the same axis; they are separated only by a slight constriction. In *Limax* the divisions of the centre of the circulation are placed on different axes, and more individualized. In this latter genus it is planted in the centre of the respiratory plexus, and also in that of the cavity. In *Helix* it is situated at the posterior boundary of the chamber.

The roof in this shelled genus is a flexible membrane (fig. 3 *b*, and figs. 4 & 5 *c*). It is fixed posteriorly to a sort of diaphragm (fig. 3 *i*) which imperfectly divides the thorax from the abdomen (*j*). In the substance of the roof is lodged a stratum of muscles which contract and relax synchronously with the expiratory collapsing and inspiratory expanding of the cavity. These respiratory movements are very markedly defined in the animal of *Helix* removed carefully from its shell (figs. 4 & 6). The fixed position afforded by the ligament which ties the body to the columella, yields important service in the mechanical acts of respiration.

The soft abdominal segment (fig. 3 *j*) of the body is covered by a continuation of the mantle. In this situation the membrane is thinner, smoother and more delicate. *It is quite adherent everywhere to the subjacent organs.* There are no vacuoles either between it and the invested viscera, or between the viscera themselves. During retraction the foot may be concealed completely in the cavity of the thoracic moiety of the animal. This explains why it is that the viscera (brain, œsophagus, portions of reproductive and chylopoietic viscera, &c.) are so loosely packed in this region, and why it is that large spaces filled with fluid lie intermediately. Such vacuoles are more spacious in the Helicidæ than in the Limacidæ, because in the former the head and foot are more retractile than in the latter. The anterior surface or front of the operculum is perforated on the right side by a large, valvular, irritable sphincteric orifice (figs. 4 & 5 *a*, *a*). In the edge of the mantle directly above this orifice is observed a deep notch (fig. 4 *e*), which, when the animal is tightly coiled up into itself, fits over the orifice. By this simple contrivance, under all circumstances, the patency of the communication between the breathing-chamber and the external air is secured. So important is this point, that, both during hybernation and when the animal remains long attached to a dry calcareous stone in arid seasons, the membranous epiphragm which is then formed from the mucus supplied by the mucus-gland, is valvularly perforated at a point corresponding to the respiratory orifice. Respiration therefore, though sometimes greatly reduced in amount, at no time during the life of the animal completely ceases.

The pulmonary plexus, which in *Helix* is restricted to the roof of the cavity (fig. 3 *h*), presents a much more regular and symmetrical arrangement of the vessels than that of *Limax*. In *Helix* a main vessel (*d*, *d*) runs obliquely from left to right along the vault of the cavity; it terminates by dilating into the auricle (*c*); it commences at the anterior border (*d'*) in branches which converge upon it with great regularity of course. The lateral trunks are similarly regular. In some places the ultimate vessels can be traced with the naked eye: they are best viewed as opake objects, by cutting off the entire roof and placing it, vessels uppermost, between two slips of glass, and then examining with a two-inch or an inch object-glass. It will be observed that the primary or large trunks (fig. 6 *a*, *a*, *a*) run, on the whole, in parallel directions, enclosing interspaces of pretty uniform diameters; and that the secondary branches (*b*, *b*) proceed from the primary also in a determinate manner, separated by tolerably uniform distances, and running in tolerably orderly directions, so that they leave between them spaces which manifest a tendency to symmetry of outline and regularity of areæ.

The ultimate vessels (fig. 6 *c, c*) undoubtedly obey a similar method of distribution. If a spot be taken for inspection in which they are densely present, the vessels will be found to lie in parallel columns (as represented in Pl. XI. fig. 6, which has been drawn with great care from the actual object). In other places, especially towards the circumferences of the roof, they exhibit a more sparse and less regular distribution. If such portions of this vascular membrane were folded in the "ridge and gutter" fashion, taking care that the secondary vessels coincided with the borders of the folds, a *branchia* would be formed whose structure would conform with the *laminose* principle. It may conversely be said, that the lung of the air-breathing Gasteropod is nothing but the branchia of the water-breathing Gasteropod, having the laminæ of the gill so unfolded as to form a straight sheet. This comparison is really not too far-sought. In both instances the ultimate vessels present a uniform cylindrical character, seldom intercommunicating: such a comparison, however, is quite untenable in the case of *Limax* (fig. 2). Here the plexus is arboriform and irregular, circumscribing areæ of various sizes and figures. Like that of *Limax*, the lining of this cavity in *Helix* is undoubtedly ciliated at various parts. It is only possible to detect the presence of cilia along the lines of the larger vessels, and here and there in creases in their vicinities.

From the author's observations, it is probable that the spaces between the larger vessels, and coinciding with the capillary areæ, are devoid of *ciliated* epithelium. Nor is it easy to separate the layer of epithelium by which these parts are covered, from the elements of which the coats of the vessels themselves are composed.

In *Helix* the coats of the pulmonary vessels (fig. 3 *h*) are considerably less calcified, less white in appearance, and more flexible than those of *Limax*. They afford, therefore, a more favourable opportunity for determining their minute structure.

The same surprise may be expressed with respect to this lung-sac as with respect to that of *Limax*, viz. that so limited a vascular area presenting vessels so coarsely subdivided, should suffice, in so bulky an animal, to supply the demands of the respiratory function. While all other animals, even those inferior to these Mollusks in serial standard, are furnished with organs which involve prodigious superficies for action, how is it, it may again be asked, that in these superiorly endowed Gasteropods so rudely constructed an apparatus, so carelessly formed an organ should be enabled adequately to discharge a function so imperious?

Can there be any peculiarity in the structure of the vessels? As the calcareous layer is less developed here than in *Limax*, it is obvious that the presence of this layer is not an indispensable constituent of the organ. The pulmonary vessels in the Snail exhibit a structure which cannot well be proved to exist in the Slug. Their coats bulge out in a cellular-like manner. This occurs all round the circumference of each vessel, most distinctly in the smallest. It is impossible to determine whether the convexities on the exterior correspond with concavities on the interior of the vessels. But, by inference from the character of the outside, it seems almost certain that such an arrangement does really exist. If it does, it is not difficult to understand how considerably it is calculated to augment the surface of contact between the blood and the air. Though such cellulated parietes might mechanically slacken the speed of the current, the function of the part cannot fail to be considerably raised in amount.

Lymneadæ.—"These freshwater pulmoniferous snails constitute a very natural family, the animals of all bearing a great similarity to each other, and being similarly organized. All have short, broad snouts, and two tentacula of considerable size, either triangular or subulate in shape, with eyes placed at their inner bases." (Forbes and Hanley.) Little has been done by anatomists to elucidate the structure of this interesting family. In several features they approximate closely to the Helicidæ. The most striking character is the siphon-like tube into which the respiratory orifice is prolonged. This siphon (fig. 7 *a*) is capable of being considerably extended beyond the edge of the mantle (*b*). When the animal is floating reversely near the surface of the water, it may be seen from time to time to be slowly pushed above the surface into the air. At this moment, and through it, the effete contents of the respiratory cavity are emitted, and a supply of oxygen is drawn in. So wonderfully sensitive and discriminative is this little organ, that it opens only when it peeps into the atmosphere. Water never enters into the pulmonary chamber of *Lymneus*. The same observation applies to *Planorbis*.

But in these water-snails the breathing-chamber (fig. 7 *c*) is more actively ciliated than in the terrestrial families. Not because they breathe at any time on the aquatic principle, but probably because the whole tissues in these water-inhabiting genera are less calcified, and therefore more favourable to the development of cilia. It must, however, be supposed from these statements that the breathing-chamber is lined with a continuous layer of ciliated epithelium. It is detectible only on certain parts which chiefly correspond with the lines of the large trunks. The Limneids differ from the Helicidæ in being furnished with a richly ciliated epithelium on the *exterior* of the respiratory cavity. In young specimens vibratile cilia may be detected over the entire abdominal portion of the body. In the old, however, it disappears from this region, and is replaced by a non-ciliated variety.

In *Planorbis* the distribution of cilia is more limited. It is detectible on the siphon and margins of the thoracic cavity. With care it is possible to lay open or to remove the roof of this cavity in a large specimen of *Lymneus*, fixed by pins whilst floating in water. The roof delicately cut away is placed between two slips of glass and examined as an opake object. The larger vessels present a general arrangement analogous to that formerly described in *Helix*. A large central trunk runs obliquely from the left anterior to the right posterior angle of the cavity (fig. 7 *d*). It is the main venous channel which terminates in the auricle (*e*). The lateral or secondary trunks converge upon the line of this vessel from all sides. It is scarcely possible, in consequence of the absence of lime from the coats of the vessels, to trace the distribution of the ultimate channels. From glimpses obtained here and there, it is however most probable that they observe a parallel mode of division such as that already represented in the Helicidæ. The heart differs from that of *Helix*. The ventricle stands at an angle on the auricle. The axes of these two divisions meeting at the auriculo-ventricular orifice would form nearly a right angle. The gland (*f*) occupies a position to the left of the heart; it resembles that of *Helix*; it is an oval flocculent mass. To the right of the heart, the rectal intestine (*g*) enters within the precincts of the respiratory cavity; it traverses the chamber along its floor, and terminates in the siphon (*a*).

The breathing-chamber in the Lymneadæ exceeds that of all other air-breathing Gasteropods in size relatively to that of the body. The surface for the outlaying of the pulmonary plexus exhibits a greater relative area. The pulmonary sac of *Planorbis* is probably organized after the model of that of *Lymneus*. It is formed however on too small a scale to admit of a direct and satisfactory examination. The siphon is extensile like that of *Lymneus*, and like that of the latter genus, the cavity communicates externally by means of the siphon alone.

[To be continued.]